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DRAG REDUCTION ON SPHERICAL BODIES
DUE TO CERTAIN ADDITIVES IN WATER.

Drug Rec

[illegible]

$$\text{Drag reduction} = 1 - \left(\frac{[illegible]}{\text{velocity in [illegible]}} \right)$$

4. [illegible] of Results:

Fluid	Percent Drag Reduction for [illegible]				
	1/2"	9/16"	[illegible]	[illegible]	[illegible]
1.0% JZFP Guar II	-	-	-	[illegible]	[illegible]
0.5% JZFP Guar I	-	-	31.5(16)	[illegible]	[illegible]
0.5% JZFP Guar II	-	27.0(5)	[illegible]	[illegible]	[illegible]
0.25% JZFP Guar I	-	-	27.0(8)	[illegible]	[illegible]
0.25% JZFP Guar II	-	-	23.0(5)	[illegible]	[illegible]
0.125% JZFP Guar I	-	-	-	11.0([illegible])	[illegible]
0.75% Polyox 301	20.0(4)	-	-	-	
0.50% Polyox 301	15.5(4)	15.0(7)	14.0(6)	-	[illegible]
0.25% Polyox 301	12.5(5)	-	-	-	[illegible]

NOTES:
1. The numbers in parentheses show the number of observations used to [illegible] the results.
2. In the Guar II solutions, sugar was added to the guar to facilitate [illegible] going into solution.

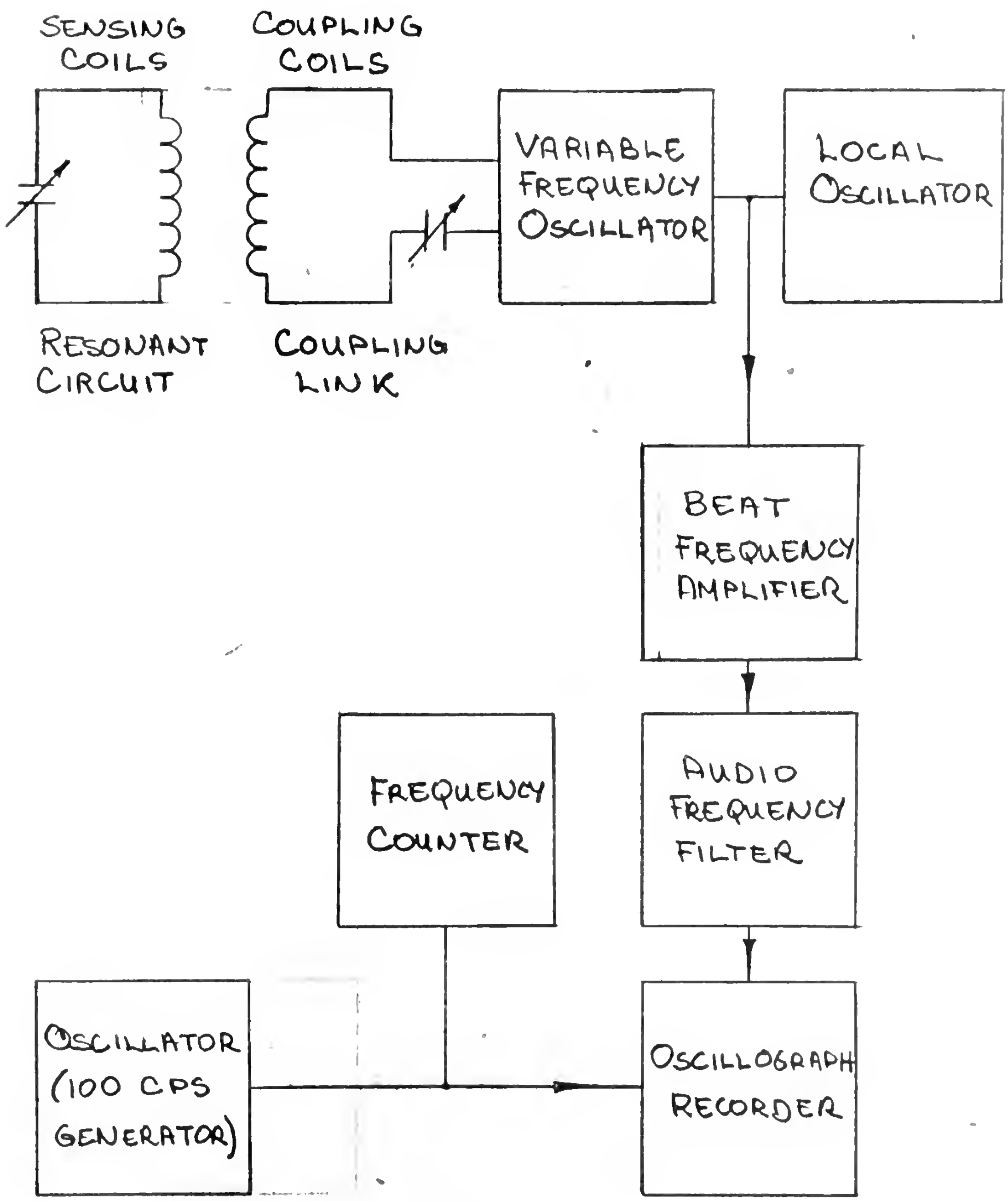
5. Accuracy of Results: [illegible] the simple arithmetic mean of the total number of observations. [illegible] made to determine standard deviations, probable accuracy, etc. [illegible] for a given set of observations there was little deviation, and [illegible] conservative estimate of the accuracy of velocity measurements [illegible] where five or more observations were made is ± 4%.

[illegible]

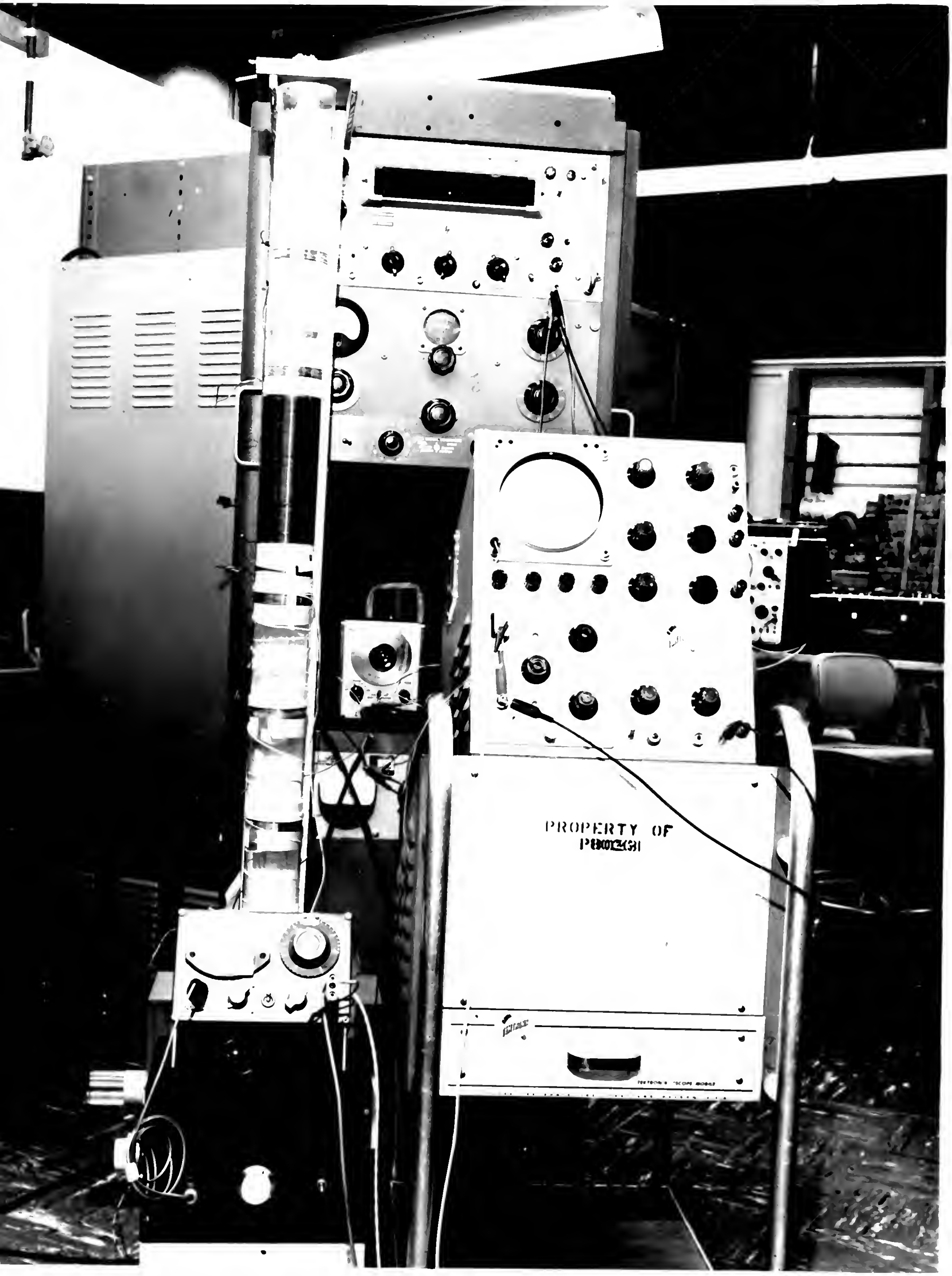
6. General Discussion: [illegible]

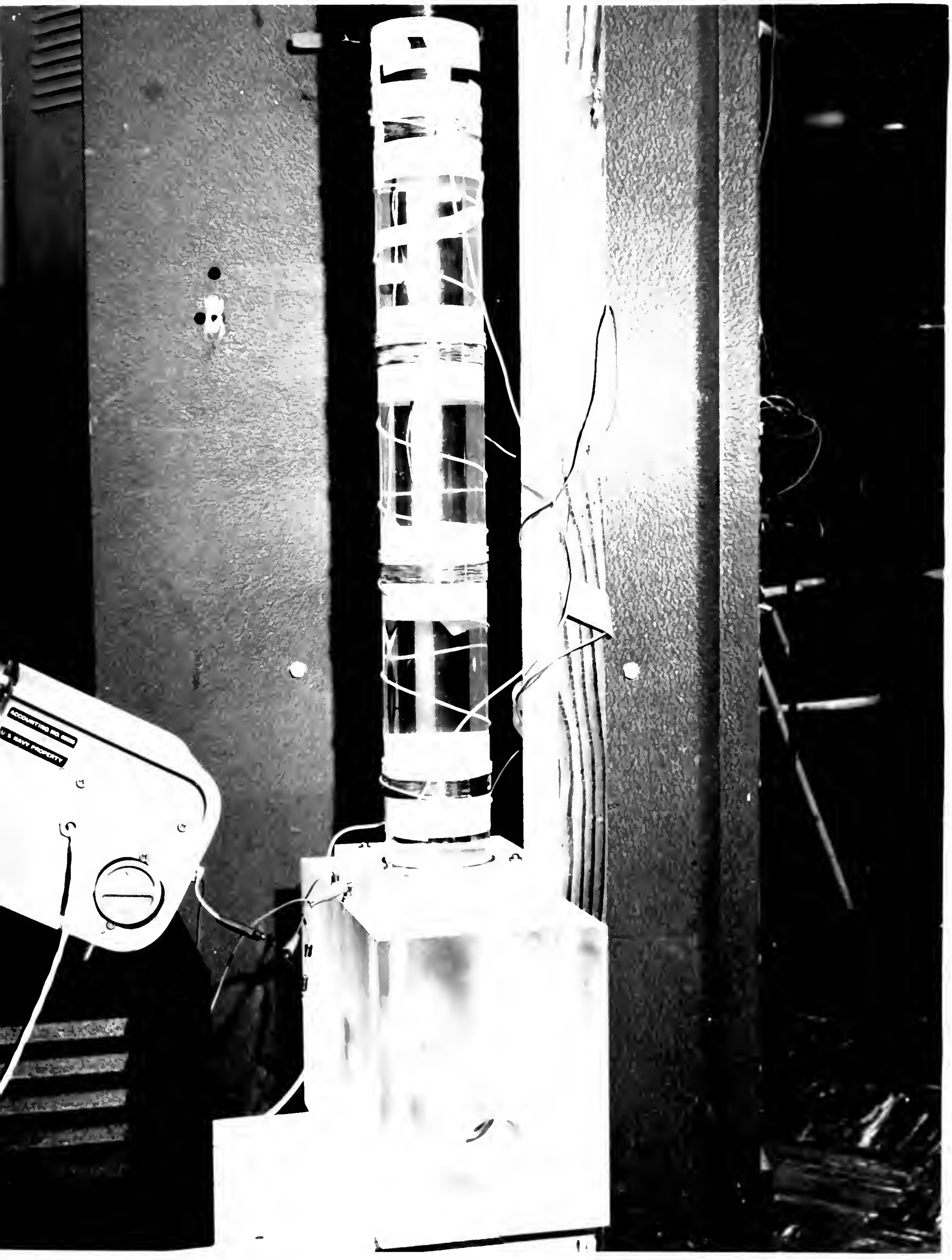
[illegible]

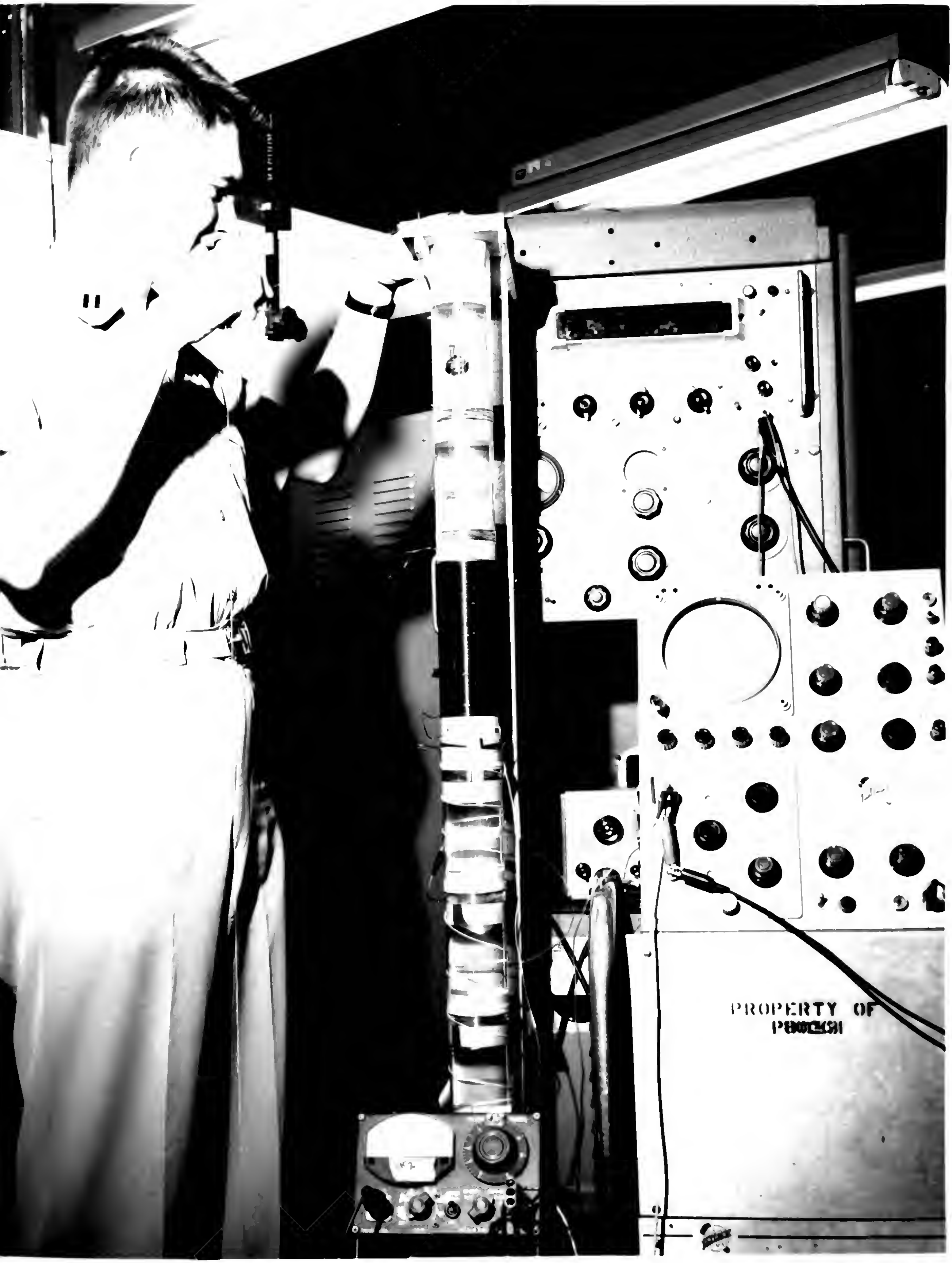
Block Diagram of Experimental Set-up



DEPICTION OF EQUIPMENT USED




ACCOUNTING NO.
U S NAVY PROPERTY


PROPERTY OF

DERIVATION OF FORMULAS USED

Symbols

W - Weight of sphere
B - Buoyant force on sphere
F - Net force on sphere $= W-B$
v - Velocity
k - Drag constant of proportionality $= \frac{1}{2} A \rho C_D$
C_D - Coefficient of drag
A - Cross-sectional area of sphere
ρ - Density of fluid
x - Distance of fall
g - Acceleration due to gravity

(All units in ft-lb-sec system)

[From $F = ma$]

$$W - B - kv^2 = ma = \frac{W}{g}\frac{dv}{dt} \qquad v = \frac{dx}{dt} \Rightarrow dt = \frac{dx}{v}$$

$$(F - kv^2)\,dx = \frac{W}{g} v\,dv$$

Thus $x = \frac{W}{g}\int \frac{v\,dv}{F - kv^2}$

or $x = \frac{-W}{2gk} \ln\left(v^2 - \frac{F}{k}\right) + C$ (constant of integration)

Setting $v = 0$ when $x = 0 \Rightarrow C = \frac{W}{2gk}\ln\left(-\frac{F}{k}\right)$

$$\therefore x = \frac{W}{2gk}\left[\ln\left(-\frac{F}{k}\right) - \ln\left(v^2 - \frac{F}{k}\right)\right]$$

$$x = \frac{W}{2gk}\left[\ln \frac{-F/k}{v^2 - F/k}\right] \Longrightarrow e^{\frac{2gk}{W}x} = \frac{-F/k}{v^2 - F/k}$$

Solving for v:

$$\longrightarrow \quad v = \left[\frac{F}{k}\left(1 - e^{-\frac{2gkx}{W}}\right)\right]^{\frac{1}{2}}$$

Note: Terminal Velocity $= \sqrt{F/k}$

A Conservative Approximation for Drag Reduction

(Assumes terminal velocity has been reached in both the fluid tested and water.)

$$\text{Drag Force} = F = \tfrac{1}{2} A \rho C_D v^2$$

$$\text{Drag Reduction} = \frac{\text{Drag in } H_2O - \text{Drag in Fluid}}{\text{Drag in } H_2O}$$

$$\cong \frac{C_{D_{H_2O}} - C_{D_{Fluid}}}{C_{D_{H_2O}}}$$

$$\cong \frac{\dfrac{F}{\frac{1}{2} A \rho v_{H_2O}^2} - \dfrac{F}{\frac{1}{2} A \rho v_{fluid}^2}}{\dfrac{F}{\frac{1}{2} A \rho v_{H_2O}^2}}$$

$$\cong 1 - \left(\frac{v_{H_2O}}{v_{fluid}}\right)^2$$